## Art. LII.—*On Ocean Wave Power Machinery.*

By S. R. Deverell, Esq.

[Read 9th December, 1872.]

This invention for utilising ocean wave power on board sea going vessels consists—in its most abstract form—of a heavy mass freely poised in all directions upon a medium of compressed air, or other elastic medium, (or by atmospheric pressure acting against a vacuum,) so that it is absolutely independent of the motion of the ship. This perfect freedom is obtained by referring it to three dimensions at right angles to each other; viz., a direction fore and aft, called the first dimension (the terms vertical and horizontal being clearly inapplicable to a vessel oscillating on waves); a direction athwart ships (called the second dimension); and a third dimension at right angles to the two former or to the plane of the deck, and corresponding to the term vertical in its land signification. Thus, every movement of the vessel in whatever direction, produces a counter relative impulse of the freely poised mass in the opposite direction, the force being jointly proportioned to the mass employed, and the resultant of all the wave forces acting upon the ship. The movements in the three separate dimensions, and which of course are irregular in their character, are reduced to a uniform direction, and added together by double action ratchet wheels and epicyclic gearing, the combined movement being made to merge in the rotation of a single shaft constantly in one direction.* This shaft compresses air into a receiver, and the compressed air so stored up is then used in the same manner as steam in a high pressure engine, with the usual appliances for regulating the supply and action.

Each movement of the vessel, however slight, thus contributes a volume of compressed air, the magnitude of which, owing to the hugeness of the force which moves the ship, can be controlled within.

From this elementary statement of the principle it will be seen that the mass is opposed only in all directions by the resistance or work to be done; and valves for preserving, increasing, or diminishing the density of the compressed air,

* Wheels may be altogether dispensed with, and valves substituted in their place, water being employed as an incompressible medium in compressing the air, in the same manner as in the appliances used in the Mont Cenis railway tunnel.

at all times furnish a ready means of regulating such resistance either by self-action or at will.

For the same reason there can be no shock to the machinery, for the principle of action being perfect freedom in all directions, no matter how violent the shock which the vessel sustains from the waves, the mass or independent load pursues its relative motion until gradually dispossessed of its force by the compressed air. Any shock to the machinery would in fact imply that the principle of the invention had not been carried out, and that the mass should have freedom in that direction.

In actual practice it is proposed to insert intermediate mechanism between the independent mass and the compressed air, to produce a mechanical advantage for economy of space in the volume of the air receiver. No other advantage is gained by this: the source of power, viz. the oscillations of the vessel, being of course the same.* But it will be thus apparent that the mechanical forms of application of the principle may be as infinitely diverse as machinery itself.†

An idea of the ultimate principle of action may be gained by balancing a heavy cube of metal by elastic springs attached perpendicularly to the six faces of the cube; every force actuating the outer or containing body will be exerted upon the springs in the opposite direction by the cube, the resultant of the relative forces thus expanding or compressing the springs being equal to the whole relative force resident in the cube, or to its *independent inertia.* Some idea of the magnitude of the force thus engaged may be had from witnessing the movements of the ponderous balance beams employed in pumping deep mines, such for instance as are commonly used at Bendigo. Yet, such an impulse illustrates the operation of the force in one dimension only.

It has been asked what would be the effect upon the ship, of so heavy a mass moving within board. If the movements in the three dimensions be referred to three *axes* at right angles to each other, the pressure being transferred to the fixed bearings, the effect upon the ship is the same as if the mass had no motion, but were a rigid part of the ship at

* By oscillation is not meant the angular oscillation only, as has been supposed, but the resultant of the vertical, the horizontal, *and* the angular oscillations, which makes a large difference in the right conception of the nature of the power.

† Fluidity is itself a mode of independent inertia, and forms of the invention may be constructed in which it is the agent.

the bearings, and actually stationary at those points.* But reference to the theory of action will show that such an arrangement is practically unessential.

For the motion or play of the mass, or load, is resisted at all points only by the work to be done. The actual play or movement may consequently be reduced at pleasure by increasing the resistance or work imposed upon it: every such governance being self-acting; in accordance with the fundamental principle of dynamics, that the mechanical efficiency, or work done, is not diminished by diminishing the play and increasing the resistance. The play, therefore, of a few inches is equally as efficacious as if the mass have almost untrammelled motion. The movement may, therefore, be made so small as to be wholly inappreciable in regard to its effect upon the ship; and a double purpose so served in economy of space. For as the dead weight which *has* to be carried in a ship may be employed as the moving mass, the loss of space is the extent of the movement only, which may be thus indefinitely reduced. In practice it is proposed in such a case to employ a moveable deck or frame carrying fifty tons or upwards of dead weight, with an allowed movement of no more than twenty inches.†

The mode in which it is absolutely confined between fixed limits is by directly connecting the movement of the mass with throttle valves, which cut off the space into which the air is compressed; and by a governor regulating the outflow of compressed air into the engine.

By these means the density of the air is sustained at a degree proportional to the power supplied, *i.e.*, to the violence of the oscillations, so that resistance increases in proportion to the magnitude of the force represented by the oscillations; or, in other words, the work imposed is kept precisely equal to the power supplied, and the extent of the movement thereby controlled. In fact, if the resistance be increased so much by wholly or partially closing the valves, as to equal the relative force in the mass arising from the action of the wave forces, the movement would be

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* As some misconception has been published on this subject, it may be as well to state definitely, that when so referred to three *axes* at right angles to each other, it is mathematically *impossible* for the movements of the independent load to affect in the slightest degree in any way, the stability of the ship, other than if it (the load) were rigidly fixed.

† The machinery itself will occupy the same space as the engines and boilers of a steam engine; the parts being analogous, the saving being in the large space occupied by coals.

reduced to zero, *i.e.*, no work would be done and the mass would move *absolutely* with the ship, as a rigid part of her.

It will be seen that in the application of the principle, compressed air is proposed to be used for three several purposes.

1st. As an elastic medium on which the load is poised.

2nd. For storage of power.

3rd. For regulating velocity.

It is not however absolutely essential to the principle, and other means for effecting these objects can be employed. It is however cheap and always accessible ; but on the other hand, its alternate expansion and contraction will engender differences of temperature necessitating the use of further machinery to overcome ; unless indeed the difference of temperature itself be applied to a useful purpose.

Instead of freedom in three dimensions, the apparatus may be so constructed as to have freedom only in any one or two dimensions. Thus, in a combination of the first and second dimensions, the independent mass would be free to move in the plane of the deck only or upon curved surfaces upon the plane of the deck by the apparent action of gravity; apparent only because the relative rise or fall may be absolutely the reverse. The actual motions of any point in a vessel oscillating on waves, and the relative motions of a body free to move within her *at* that point, include many difficult problems too abstruse to be briefly mentioned here, but the investigation of which, with the result of actual experiments on the subjects now being prepared, will be shortly submitted. In a paper previously read (at the Royal Society of Victoria,) it was however shown that the oscillation of a ship amongst waves is compounded of three simultaneous oscillations, vertical, horizontal, and angular; and there can be no oscillation at all in which any one of these three be absent. That is, for instance, a vessel or any part of her cannot oscillate vertically without also a horizontal sway and an angular deviation and *vice versa.* Hence, as the whole oscillations of a vessel are practically unceasing as long as she is on the open ocean, so also are each of these. This fact is of great consequence in estimating the efficacy of the various forms of construction which the principle may assume ; the writer having experienced a good deal of difficulty in removing the prevailing error, that the mere roll of a vessel is equivalent to her whole oscillation. The rolling is only a part of the

movement into which the whole oscillation is divided ; and any estimates based on this somewhat tenacious fallacy are of course erroneous.

The degree of independence or freedom of the mass is jointly proportional to the *volume* and the density, of the elastic medium on which it is poised. Hence, the power will be estimated by assuming *perfect* independence and multiplying the result by the co-efficient of elasticity.

By observations made expressly during three voyages in vessels of 300, 800, and 1,200 tons respectively, it is estimated that an ordinary sea-going vessel on a deep-ocean voyage averages six oscillations per minute, with the *average* angular inclination of 9° thus compounded, viz., 8° 39′ on the longitudinal or rolling axis, and 2° 30′ on the transverse or pitching axis ; and that the whole movement constantly to be relied on, represents an efficient force of independent inertia, combined upon the three dimensions, equivalent to the whole mass raised at the rate of 14 inches per second ; so that if the mass or independent load be represented by *M*, the working effect will be equivalent to 4·7 *M* horse power or upwards of 4½ horse power per ton of weight employed.*

The storm efficiency is of course very much greater ; indeed to those acquainted with the behaviour of ships in heavy seas, little demonstration is necessary to show that in a vessel labouring amongst waves 20 or 30 feet in height, the prodigious force accumulated will exceed practical requirement, and the movements of the load may be reduced almost to zero.

In a forthcoming analysis of the principle of action, it will be shown that it is precisely the same as if the vessel remained motionless, and the inverted movements of the ship were transferred to the independent load ; the working power consisting of the force requisite to stop such a movement.

It will thus be seen that as the movement of the ship is the resultant of all the wave forces acting within the total displacement, the entire vessel presents the surface from which the force is gleaned. In other words, she is the receptacle of the moving force of all the particles of water which she displaces ; a power so enormous as to be practically infinite in respect of any tax which can be imposed upon it from within board, so that it may not be too much to assert

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* The computation on which this result is based will hereafter be shown.

that the maximum power derivable on this principle is limited ultimately only by the strength of materials.*

Be it remembered that this vast power is most active and available precisely in those emergencies when it is most needed, when human effort is futile and a vessel is at the mercy of the waves. If indeed we consider the effect of a sluggish stream upon a water-mill and compare the ceaseless progress of the waves of the ocean, the various uses to which the huge power conserved in them could be applied, it may surely be regarded as remarkable that a power, probably the greatest and most universally spread in the world, should remain unapplied, and that fleets of vessels should be annually destroyed by the very force which can be employed to their preservation.

Ocean wave-power in itself is the aggregated force of the winds instead of their direct force as represented in sail-power, and the advantages sought to be obtained in its application are: 1st. That the power is more continuous and reliable than the direct action of the winds or of sail power; it having been conclusively proved that on *the open ocean wave action never ceases* during the most continued calms of wind. 2nd. That, constituting a compromise between sail and steam-power, its adoption would reduce very considerably the cost of heavy and expensive rigging. 3rd. That its action is independent of contrariety of winds. 4th. The average actual power is greater than in the direct action of the winds: it being an essential distinction that whereas sail power employs *surface* to catch the force, this, viz. the indirect or automatic application of wave power engages

* The idea of utilising ocean wave power is almost as old as the present century; and vessels have been repeatedly saved from foundering by its means. The power in such cases has been derived from the direct action of the waves by means of spars or moving frames placed overboard, and taking advantage of the vertical oscillations of the waves. It is obvious that, apart from the generally impracticable character of such arrangement, the power is proportional only to the section of the float or frame employed; the essential distinction of the present application being that the apparatus is wholly within board or automatic, and the power is derived from the forces acting upon the entire vessel.

Notwithstanding these signal advantages, some of the old plans have been revived since attention was drawn to the subject by the present writer; and previous instances of automatic appliances have been cited; the latter, however, in apparent ignorance of the nature and source of power, and therefore applying only a part of the principle. In point of fact the force is and *always has been* used constantly by seamen *empirically*. Every seaman knows, for instance, the right moment when to run in with the slacking strain on a rope—and the mere lowering of a cask to the lee side affords a practical exemplication.

*mass* for the same purpose. Lastly, the force can be applied to a large number of purposes, viz., pumping, the extinction of fires, ventilation, reduction of temperature and others, as well as to auxiliary propulsion.

The comparison is made with sailing ships, because on account of the great cost and inconvenience of fuel for steam-power at sea, sailing ships still successfully carry on the bulk of the world's commerce; and if their only drawback, viz. the unreliability and contrariety of the winds which impel them can be overcome, as is proposed to be done on this principle, by applying the indirect but cumulated force of those winds, it may, notwithstanding unreasoning prejudices which such an assertion may elicit, be found unnecessary to import fuel from the land, when nature has provided a never ending supply of the vastest force ever at hand on the highway of the ocean.

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## Art. LIII.—*The Classificatory System of Kinship.* By Rev. Lorimer Fison.

[Read 9th December, 1872.]

About the year 1848, the Hon. Lewis H. Morgan, of Rochester, New York, found among the Iroquois Indians a most extraordinary system of relationship widely differing from that with which we are familiar. He then supposed it to be an invention of, and confined to that particular tribe. But in the year 1857, having occasion to re-examine the subject, there occurred to him the possibility that it might prevail among other Indian tribes, and if so, how important a use might be made of it for ethnological purposes. Extending therefore his inquiries during the following summer, he found precisely the same system among the Ojibwa Indians, of Lake Superior. Every word used by them as a term of kinship was radically different from the corresponding term in the Iroquois; and yet in every case the meaning was the same. Before 1860, having found the system throughout the five principal stock languages eastward of the Rocky Mountains, and having moreover discovered traces of it in the Sandwich Islands, and in Southern India, he was encouraged to prosecute his researches on a more extended scale. He therefore solicited